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II

SOIL, WATER, AND VEGETATION CONDITIONS IN SOUTH TEXAS

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for Period July 13, 1976 to October 13, 1976

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<p>16. Abstract</p> <p>The LANDSAT data space surrounding the soil background line for MSS 5 and MSS 7 was divided into 10 decision regions (water; cloud shadow; low, medium and high reflecting soil; cloud tops; low, medium, and dense plant cover; and, threshold into which no LANDSAT data should fall), a table look-up procedure devised, and printer symbols assigned such that LANDSAT scenes could be gray mapped to meaningfully display vegetation density and soil conditions without prior knowledge of local crop and soil conditions.</p> <p>Reflectance (and absorptance) of plant leaves in the 0.4 to 2.5 μm wavelength interval was studied to determine best wavelengths to detect lead toxicity and ozone damage, to distinguish succulent from woody species, to detect silverleaf sunflower, and to determine wheat vigor and to distinguish wheat plants from soil. Soil-tillage-straw treated field plots were also studied for distinguishing crop residue from soil as might be important in preventing soil erosion by wind.</p> <p>The perpendicular distance from the soil background line, in MSS5 and MSS7 data space, of pixels containing vegetation has been developed and tested as an indicator of rangeland productivity and crop yield.</p>			
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Figure 2. Technical Report Standard Title Page

TYPE II QUARTERLY PROGRESS REPORT

July 13, 1976 to October 13, 1976

A. Problems:

None.

B. Accomplishments:

Studies Related to Wavelength Band Selection for Various Applications

1. Lead (Pb) Toxicity

A paper entitled "Effect of Lead on Reflectance of Mexican Squash Plant Leaves," is being prepared by D. E. Escobar and H. W. Gausman. An abstract of the paper approved for publication in the 1976 Agronomy Abstracts follows:

Mexican squash plants (Cucurbita pepo L., cv. Tatume) were grown hydroponically with four treatments: no added Pb (control) and with Pb added at rates of 100, 500, and 1,500 ppm. Leaf reflectances were measured spectrophotometrically over the 0.5- to 2.5- μ m waveband. The 1,500-ppm Pb treatment severely stunted the plants compared with the control and 100- and 500-ppm treatments. The 100- and 500-ppm Pb treatments decreased leaf chlorophyll concentrations and thereby significantly ($p .05$) increased visible light (0.5 to 0.75 μ m) reflectance at the 0.55 μ m wavelength, compared with the control treatment; near-infrared light (0.75 to 1.35 μ m) reflectance was not significantly affected. In the 1.35- to 2.5- μ m waveband, the water absorption region, reflectances for 100- and 500-ppm Pb-treated leaves were significantly lower than for control leaves at the 1.45-, 1.65-, and 2.2- μ m wavelengths.

2. Soil Erosion by Wind

A paper entitled "Field-Measured Spectroradiometric Reflectances of Disked and Nondisked Soil With and Without Wheat Straw," has been prepared by H. W. Gausman, R. W. Leamer, J. R. Noriega, R. R. Rodriguez, and C. L. Wiegand. An abstract of the paper follows:

The objective was to compare field-measured spectroradiometric reflectances of nondisked bare soil with or without littered wheat (Triticum aestivum L.) straw and bare soil that was disked directly or after littering with wheat straw. This information is needed to develop a procedure for predicting potential soil erosion using aircraft or satellite multispectral scanner reflectance measurements.

A ground-based spectroradiometer was used to measure reflected radiation from six soil-tillage-wheat straw treatments: disked and nondisked soil with and without two wheat straw rates---equivalent to 2.24 and 4.48 metric tons/ha, respectively.

The near-infrared region (0.75 to 1.3 μm), exemplified by the 1.05- μm wavelength, appeared to be better than the visible (0.45 to 0.75 μm) or water absorption wavebands (1.5 to 1.8 μm and 2.0 to 2.5 μm) for distinguishing among reflectances of the soil-tillage-straw treatments.

Results indicated that LANDSAT multispectral scanner's band 7 (0.8 to 1.1 μm) might be used to distinguish nondisked bare soils from those with different amounts of straw on their surface; however, there probably would be some confusion among spectra of nondisked bare soils, disked bare soils, and disked soils with low amounts of straw incorporated in them.

Further research is needed on the effects of other soils, soil moisture contents, kinds and amounts of plant residue, tillage operations, and their interactions on reflectance.

3. Plant Discrimination and Leaf Anatomy

A paper entitled "Relation of Peperomia obtusifolia's Anomalous Leaf Reflectance to Its Leaf Anatomy," has been prepared by H. W. Gausman, E. B. Knipling, and D. E. Escobar. An abstract of the paper follows:

We explained the absence of a near-infrared light reflectance peak, at about the 2.2- μm wavelength, from Peperomia obtusifolia A. Dietr. leaves by comparing their spectrophotometric measurements for upper and lower surfaces and anatomical components, including untreated, dehydrated, and hydrated hypodermises. This absence was caused by light absorptance by water stored in the cells of Peperomia's leaf hypodermis. This additional knowledge about the interaction of light with plant leaf anatomy supports previous evidence that future design of multispectral scanners should include a waveband centered about the 2.2- μm wavelength to enhance plant species discrimination by remote sensing.

4. Ultraviolet Light (UV-B) Damage to Plants

A paper entitled "Leaf Ultraviolet Light Reflectance, Transmittance, and Absorptance of Ten Crop Species," has been prepared by R. R. Rodriguez and H. W. Gausman. An abstract of the paper follows:

High-flying crafts' effluents or chlorofluoromethane refrigerants and aerosol can propellants that diffuse to the stratosphere might reduce atmospheric ozone and increase the amount of middle-ultraviolet or UV-B radiation (280 to 315 nm) reaching the earth's surface with possible biologically damaging effects. We spectrophotometrically measured the leaf reflectance, transmittance, and absorptance of UV radiation over the 260- to 360-nm waveband for 10 crop species: blackeye pea, corn, cotton, grain sorghum, pinto bean, redblush grapefruit, soybean, sugarcane, sunflower and tomato. The 10 crops' leaves reflected from 4 to 6% and absorbed from 94 to 95% of UV-B radiation;

none was transmitted. Therefore, outer plant canopy leaves might protect inner canopy leaves from damage by absorbing all the nonreflected UV-B radiation. However, the transmissivity of UV-B damaged crop leaves needs to be determined.

5. Ozone Damage to Plants

A paper entitled "Reflectance Measurements and Photographic Previsual Detection of Ozone-Damaged Cantaloupe Plants, (Cucumis melo L.,) is being prepared by H. W. Gausman, D. E. Escobar, R. R. Rodriguez, and C. E. Thomas. The highlight of the paper follows:

Ozone accounts for up to 90% of pollution injury to vegetation in the United States; excess ozone affects plant growth, development, and yield. Yield reductions may even occur from damage too slight to be seen. Laboratory and field reflectance measurements showed that ozone-damaged leaves were less hydrated and reflected more light than nondamaged leaves. Cantaloupe plants with artificially induced light, severe, and very severe ozone damage were easily distinguished from nondamaged plants by reflectance measurements in the 1.35- to 2.5- μ m near-infrared wavelength band. Sensors are available for use with aircraft and spacecraft that may some day be finely enough tuned to routinely detect ozone damage to crops.

6. Wheat Discrimination and Vigor Assessment

A manuscript entitled "Seasonal Changes in Reflectance of Two Wheat Cultivars" has been prepared by R. W. Leamer, J. R. Noriega, and C. L. Wiegand. An abstract of the paper follows:

A ground-based spectroradiometer was used to measure the reflectance of two dissimilar cultivars of wheat (Triticum aestivum L.) over the wavelength interval 0.45 to 2.50 μ m on 9 cloud-free days between planting and maturity. Photographs of the spectroradiometer field of view were also analyzed in a density slicing, image analyzing system to determine the area of soil, sunlit vegetation, and shadow in each photograph.

All reflectance curves had the characteristic shape for vegetated surfaces by 4 weeks after emergence. Penjamo, a nontillering Mexican wheat with typical spring wheat development cycle, was not spectrally different from Milam, a cultivar that tillers and has a winter wheat development pattern. Three seeding rates (50, 103, and 162 kg/ha) affected the rate of ground cover but not the spectra once sunlit vegetation filled \approx 25% of the spectrometer's FOV. Except at the end of the season when the plants senesced and lost pigmentation, changing proportions of exposed soil versus vegetation were more important than development stages in determining spectral responses.

Detailed examination of the seasonal responses at 7 wavelengths, 0.55, 0.65, 0.73, 0.90, 1.10, 1.65, and 2.2 μ m, characteristic of

LANDSAT and LANDSAT follow-on mission bands showed that: (a) responses in the wavelength pairs 0.65 and 0.73 μm (visible red and far red), 0.90 and 1.10 μm (reflective infrared), and 1.65 and 2.2 μm (peaks between water absorption bands) were similar, indicating that only one of each pair would be required to represent a scene composed of soil, vegetation, and shadows, (b) percent reflectance and percent vegetative cover were positively correlated for the 0.55, 0.90, and 1.10 μm wavelengths and negatively correlated for the other 4; thus the named bands yielded information directly about the vegetation, whereas the wavelengths at 0.65, 0.73, 1.65, and 2.2 μm yielded information about vegetation indirectly by the way it obscures the soil from view, (c) soil was much less reflective than green vegetation at 0.90 and 1.1 μm and much more reflective than plants at 1.65 and 2.2 μm , making each of these wavelengths valuable for distinguishing vegetation from the soil background and for assessing vegetation cover or density; as single bands 0.90 and 2.2 μm were superior to 1.1 and 1.65 μm , respectively, due to greater contrast between soil and vegetation, (d) green light (0.55 μm) reflectance was maximal and between water absorption bands (1.65 and 2.2 μm) reflectance was minimal when green vegetation development was greatest, and (e) the similar and low reflectance of wheat and soil in the visible wavelengths (0.55, 0.65, and 0.73 μm) helps explain the difficulty in distinguishing cropped from bare fields at incomplete covers with sensors such as those on LANDSAT that have a large instantaneous FOV.

7. Distinguishing Succulent from Nonsucculent Plants

A paper entitled "Distinguishing Succulent Plant Reflectance Spectra From Those Typical of Crop and Woody Plants," is being prepared by H. W. Gausman, D. E. Escobar, J. H. Everitt, and A. J. Richardson. A summary of the "Plant Species Discrimination" portion of the paper follows:

Ten plant species comprised of six succulents: [Texas tuberose (Polianthes variegata (Jacobi) Shinnars), peperomia (Peperomia obtusifolia A. Dietr), possum-grape (Cissus incisa (Nutt.) Des Moul.), prickly pear¹ (Opuntia lindheimeri Engelm.), spiderwort (Tradescantia micrantha Torr.), wolfberry (Lycium berlandieri Dun.)]; two woody shrubs [cenizo (Leucophyllum frutescens (Berl.) I. M. Johnst.), and honey mesquite (Prosopis glandulosa Torr.)]; and two agricultural crops [cotton (Gossypium hirsutum L.), and sugarcane (Saccharum officinarum L.)] were selected for laboratory spectrophotometric reflectance measurements on single leaves--one mature leaf was collected from each of 10 plants of each species.

An analysis of variance was conducted for reflectance measurements at each wavelength at 0.05- μm increments over the spectrophotometer's 0.4- to 2.5- μm waveband. Variance was partitioned as follows:

¹ Botanically, prickly pear's above ground appendages are flattened stems called platyclades, but they will be referred to as leaves here for simplicity.

<u>Source of Variation</u>	<u>Degrees of Freedom</u>
Total	99
Plant species	9
Leaves (replications)	9
Plant species X leaves	81

The analysis of variance F values (plant species variance/plant species X leaves variance) are charted in Fig. 1. Large F values, compared with smaller F values, indicated wavelengths with the most reflectance variability among plant species. Generally, larger F values occurred in the water absorption region (1.35 to 2.50 μm) than in the visible (0.40 to 0.75 μm) or near-infrared (0.75 to 1.35 μm) wavebands. Generally, wavelengths were selected for Duncan's multiple range tests, $p = 0.01$ throughout the entire 0.4- to 2.5- μm waveband where F values "peaked", except for the water absorption band valley at 1.95 μm . Wavelengths used for Duncan's test were 0.50-, 0.65-, 0.80-, 1.05-, 1.35-, 1.60-, 1.95-, and 2.20- μm . Succulent (average content of 92.2%) with low reflectance were distinguishable from nonsucculents (average water content of 71.2%) with higher reflectance (Fig. 1) at the 1.35-, 1.60-, and 2.20- μm wavelengths, but not at the 0.50-, 0.65-, 0.80-, 1.00-, and 1.95- μm wavelengths. However, the 1.60- and 2.20- μm wavelengths appeared to be best because they lie near the peak of atmospheric windows and would be accessible to remote sensors above the atmosphere. Mean differences in percent reflectances between succulents and nonsucculents for these two wavelengths were about 17 and 8%, respectively; however, reflectances among the six succulents were quite similar, and within the nonsucculents the crop plants could not be distinguished from the woody plants.

Field spectroradiometric reflectance measurements on canopies of some of the succulent and nonsucculent plant species substantiated the laboratory results.

In conclusion, sensor bands encompassing either the 1.60- or 2.20- μm wavelengths should be useful to distinguish succulent from nonsucculent plant species. This supports previous results that intervals centered around 1.65- and 2.20- μm would be useful for optimum discrimination of vegetation (Remote Sensing of Earth Resources 1:25-51, 1972; Agronomy Journal 65:194-198. 1973).

8. Detection of Silverleaf Sunflower, a Noxious Weed

An abstract entitled "Detection of Silverleaf Sunflower (Helianthus argophyllus Torr. & Gray) in South Texas Pastures by I-R Color Aerial Photography," by H. W. Gausman, R. M. Menges, D. E. Escobar, J. H. Everitt, and R. Bowen, has been approved for publication in the 1977 Weed Science Society of America Abstracts. The abstract follows:

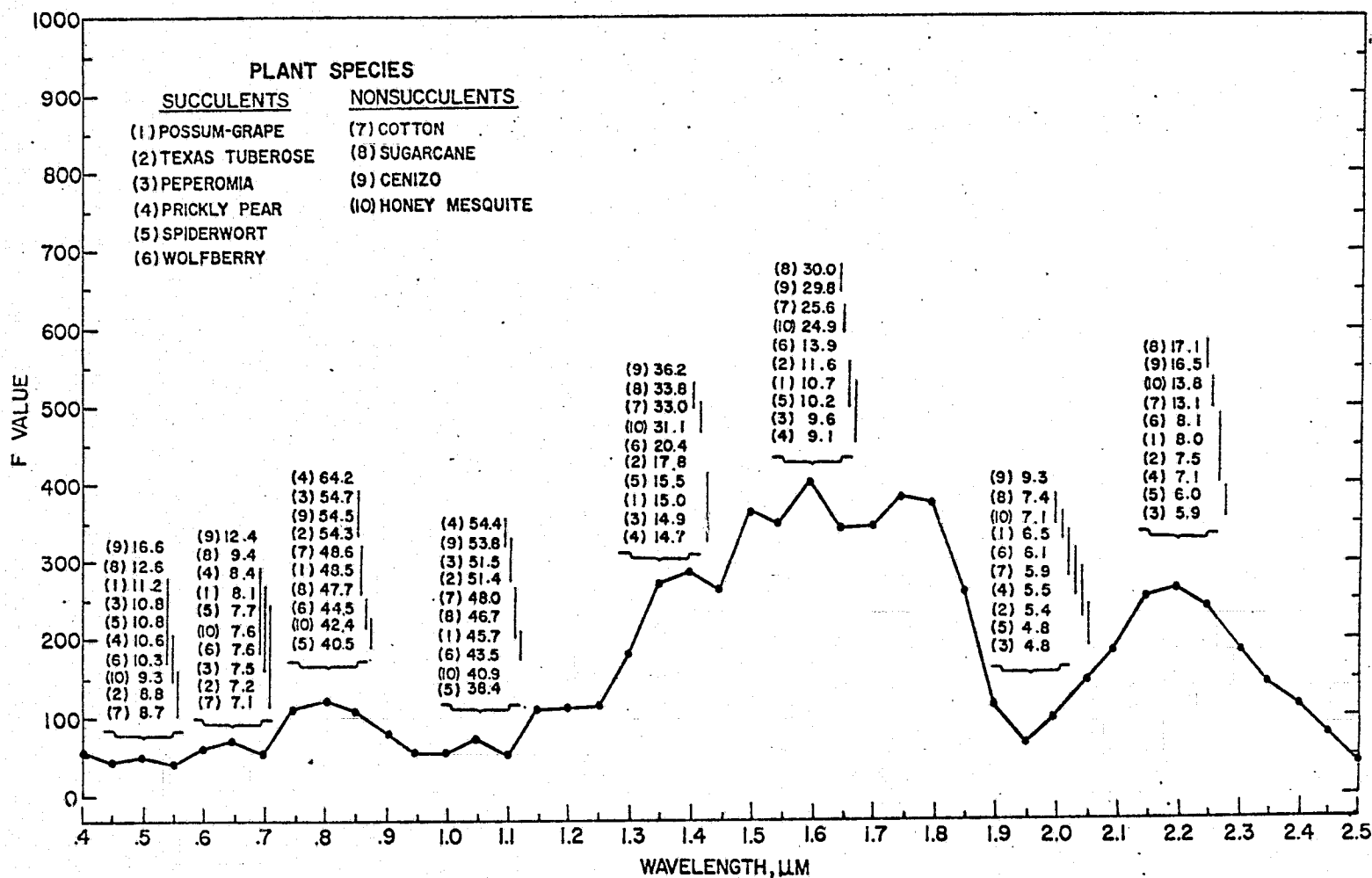


Figure 1. Chart of analysis of variance F values for reflectances of 10 leaves of each of 10 plant species at 0.05- μm increments over the 0.4- to 2.5- μm waveband. Duncan's multiple range test is given for the 0.50-, 0.65-, 0.80-, 1.05-, 1.35-, 1.60-, 1.95-, and 2.20- μm wavelengths; numbers (1) . . . (10) represent the plant species and numerals following a parenthesis represent reflectance.

Silverleaf sunflower (Helianthus argophyllus Torr. & Gray) is unpalatable to cattle and has become a problem in South Texas due to its increase in sandy pasture lands. The young plant parts of the weed are densely white-tomentose. This pubescence caused a spectrophotometrically measured fourfold and one and four tenths-fold increase in visible (0.45 to 0.75 μm) and near-infrared (0.75 to 1.35 μm) reflectance, respectively, compared with the reflectance of sparsely-hairy leaves of another sunflower species (H. annuus L.). This increased reflectance of silverleaf sunflower caused images on EASTMAN KODAK R Aerochrome infrared color type 2443 transparencies and positive prints to be "pinkish" compared with darker magenta responses for other plant species. This ability to distinguish silverleaf sunflower with I-R color aerial photography will be useful to locate its endemic areas, to monitor its spread, and possibly to effect control procedures.

Rangeland Biomass

The major range sites in Kenedy and Willacy Counties have been botanically characterized and biomass measurements have been made for the summer (July 1976) and fall (October 1976) periods. Table 1 presents the means for herbaceous biomass for the various study sites during the summer and fall season. Production was similar for the two seasons. We had ample moisture in June and July, and again in August and September, thus the range was in flush condition for both seasons.

The two improved tight sandy loam sites were the most productive sites while the tight sandy loam-native, sandy mound-native, and the salty flat were the least productive. Aliciagrass had been seeded on the tight sandy loam-improved site. It had been cut for hay just prior to the October sampling. Biomass measurements generally followed the same trend among range sites as shown during the winter and fall periods (as reported in previous quarterly progress reports). The highest biomass production occurred on those sites where brush had been controlled.

The monthly herbaceous biomass measurements on the coastal sand and deep sand-native sites have been terminated and the data are being summarized. We took measurements on these two sites each month from March 1 to October 1 to follow the productivity of each site throughout the growing season. We separated the plant material into four components: (1) apical stem fractions and heads, (2) standing brown biomass, (3) standing green biomass (green leaves and green basal stem fractions), and (4) litter. These data will be presented in the next report.

Rangeland Classification

We have recently completed classification of the 81,000-hectare study area in Kenedy and Willacy Counties using both a photo interpretation estimate and a computer identification algorithm for the December 10, 1975 LANDSAT-2 overpass. Table 2 is a comparison of the photo interpretation hectarages and land area percentages for the various land use categories

Table 1. Herbaceous biomass production (air-dry weight) for various range sites in Kenedy and Willacy Counties, Texas, sampled in July 1976 and October 1976.

Range site	Forage production	
	July 1976	October 1976
	- - - - - kg/hectare - - - - -	
Tight sandy loam-native	411	397
Tight sandy loam-improved, re-established native grasses & herbs	4047	4336
Tight sandy loam-improved, re-seeded with Aliciagrass	4910	2143 ¹
Coastal sand-native	1746	2152
Sandy mound-native	356	458
Deep sand-native	1117	1841
Deep sand-improved, re-established native grasses and herbs	2364	1874
Salty flat	487	678

¹ This site had recently been cut for hay.

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Table 2. Comparisons of photo interpretation percentages for the various land use categories with computer estimates percentages (using LANDSAT-2 MSS digital data of Kenedy and Willacy Counties study area) surveyed on December 10, 1975 (MSS bands 5, 6, and 7).

Land use categories	Photo interpretation		Computer	
	Size in hectares	Percent of study area	Size in hectares	Percent of study area
Grasslands (improved grasslands, re-established to introduced grasses, or native grasses and herbs)	2,916	3.6	19,962	24.6
Mixed brush rangeland (deep sand- native, coastal sand-native, and tight sandy loam-native range sites)	43,416	53.6	21,789	26.9
Live oak rangeland (sandy mound range site-native)	12,150	15.0	12,370	15.3
Lagunas (depressions)	3,159	3.9	5,641	6.9
Idle cropland (bare soil)	11,259	12.9	12,456	15.4
Sand dunes, tidal flats, and salty flats (predominantly bare soil)	4,374	5.4	3,474	4.3
Water	3,726	4.6	2,795	3.5
Threshold	-	-	2,513	3.1
Total	81,000	100.0	81,000	100.0

with the computer estimated areas and percentages. In four categories (grasslands; live oak rangeland; lagunas; and idle cropland), the computer estimated percentages were larger than the photo interpretation percentages, while in three categories (mixed brush rangeland; sand dunes, tidal flats, and salty flats; and water), the photo interpretation percentages were larger than the computer estimated percentages.

The largest differences in Table 2 are in the "grasslands" and the "mixed brush rangeland" categories. In an earlier classification for October 17, 1975 (see Type II quarterly progress report for period April 13, 1976 to July 13, 1976) these two categories agreed better. However, a severe frost occurred in mid-November prior to the December 10 satellite overpass, and many of the woody species (mesquite trees, etc.) lost their leaves. The defoliation of the woody species allowed much more light to come through to the herbaceous understory, thus much of the "mixed brush rangeland" was now being classified as "grassland". Most of the other land use categories hectareage percentages were fairly similar using the two classification systems. The "lagunas" category was considerably larger using the computer classification.

Criteria for Distinguishing Vegetation from Soil Background Information and Their Use in Processing LANDSAT data

A paper by the title of this section has been prepared by A. J. Richardson and C. L. Wiegand. An abstract of the paper follows:

LANDSAT-1 and -2 multispectral scanner (MSS data from six overpass dates (April 2, May 17, June 4, July 10, October 17, and December 10, 1975) showed that MSS digital data for bare soil, cloud tops, and cloud shadows follow a highly predictable linear relation (soil background line) for MSS bands 5 and 7 ($r^2=0.974$). Increasing vegetation development, documented by leaf area index measurements (LAI), for 1973 and 1975 grain sorghum crops, was associated with displacement of sorghum MSS digital counts away from the soil background line. Consequently, the perpendicular distance of a sorghum MSS measurement from the soil background line (perpendicular vegetation index, PVI) was proposed and tested as an index of plant vegetative development. Correlation of PVI with the 1973 LAI data for sorghum was significant ($r^2=0.514$) at the 5 percent probability level.

Coefficient of determination, r^2 , for the transformed vegetation index (TVI) and ratioed vegetation index ($RVI=MSS5/MSS7$) that have been used by others were 0.434 (significant at the 0.05 level) and 0.394 (not significant), respectively, for the same data set. Also, the PVI technique permits the calculation of the coordinates of the intersection of the vegetation and soil background lines; hence, it gives the position of a given pixel on the soil background line. Since position along the soil background line should vary with soil water content, soil crusting, and crop shadows, the possibility of deducing information about soil surface conditions becomes apparent.

The LANDSAT data space surrounding the soil background line for MSS5 and MSS7 was divided into 10 decision regions corresponding to water; cloud shadow; low, medium, and high reflecting soil; cloud tops; low, medium, and dense plant cover; and, a region into which no LANDSAT data are expected to fall, called threshold. It was demonstrated that, using a table look-up procedure and printer symbols for each decision region, LANDSAT study areas or scenes could be gray mapped to meaningfully display vegetation density and soil condition categories without prior knowledge of local crop and soil conditions.

Perpendicular Vegetation Index (PVI)

The perpendicular distance of MSS digital counts from the soil background line (Type II Quarterly Progress Report #6; April 13, 1976 to July 13, 1976) has been found to be a useful indicator of plant vegetative development. The greater the distance from the soil line the more dense the vegetation.

The objective here is to present the formulation of the perpendicular vegetation index (PVI):

$$(1) \quad PVI = \sqrt{(R_{gg5} - R_{p5})^2 + (R_{gg7} - R_{p7})^2}$$

where,

PVI - is the perpendicular distance between a candidate vegetation point and the soil background line,

R_p - is the reflectance of a candidate vegetation point for LANDSAT bands MSS5 and MSS7, and

R_{gg} - is the reflectance of soil background corresponding to a candidate vegetation point.

The soil background (R_{gg}) is interpreted as the intersection on the soil background line (Figure 2) of a perpendicular drawn from a candidate signature point. The coordinates of this intersection on the soil background line, in terms of MSS5 and MSS7, can be found by solving the soil background general equation ($R_{g5} = a_0 + a_1 R_{g7}$) and the vegetation general equation ($R_{p5} = b_0 + b_1 R_{p7}$), that is perpendicular to the soil background equation, for the intersection coordinates

(R_{gg5} , R_{gg7}) given by:

$$(2) \quad R_{gg5} = \frac{b_1 a_0 - b_0 a_1}{b_1 - a_1}, \text{ and}$$

$$(3) \quad R_{gg7} = \frac{a_0 - b_0}{b_1 - a_1}.$$

From Figure 2 we determined that $a_1 = 2.30$ (slope of soil background line) and that a_0 is not statistically different from zero (therefore, $a_0 = 0$). Also, since a_1 is perpendicular to b_1 , then $b_1 = -0.417$, so that $b_1 - a_1 = -2.82$. Substituting these values of a_0 , a_1 , and b_1 into (2) and (3) yields $R_{gg5} = 0.815b_0$ and $R_{gg7} = 0.355b_0$. It can be shown from the vegetation perpendicular equation that $b_0 = R_{p5} + 0.417(R_{p7})$ so that for any candidate vegetation signature defined by the LANDSAT point coordinates (R_{p5} , R_{p7}) the soil background reflectance coordinates are given by the following equations:

$$(4) \quad R_{gg5} = 0.815R_{p5} + 0.355R_{p7}, \text{ and}$$

$$(5) \quad R_{gg7} = 0.355R_{p5} + 0.148R_{p7}.$$

Thus, once R_{gg5} and R_{gg7} are determined for a candidate vegetation measurement (equations 4 and 5) then the PVI (equation 1) can be computed as a spectral indicator of plant development or biomass accumulation. Figure 2 shows that $PVI = 0$ indicates bare soil, $PVI < 0$ (negative) indicates water, and $PVI > 0$ (positive) indicates vegetation. Using these criteria any study area of interest could be delineated into soil, water, and vegetative classes without prior knowledge of the local distribution of these conditions.

Correlation of Rangeland Forage Production With PVI

Rangeland forage production (biomass) measurements made at 8 Willacy County, Texas, range sites (Table 3) on October 3, 1975 and January 6, 1976 (Type II Quarterly Progress Report #5; January 13, 1976 to April 13, 1976), were correlated with the perpendicular vegetation index (PVI) determined from LANDSAT digital data from overpasses on October 17 and December 10, 1975. These two dates represent typical rangeland forage conditions at the fall peak and dormant production seasons, respectively. Four additional sites were selected to represent bare soil conditions in the predominantly rangeland study area; idle cropland, sand dunes, tidal flats, and lagunas.

Results of correlating total forage production, measured as herbaceous biomass (kg/ha), with PVI are shown in Figure 3 and 4. For October, biomass data (peak production season) was not collected for the oak tree (O) range site due to high water. Also, the mesquite tree (M) and native brush (B) sites, where low amounts of herbaceous biomass on the ground are covered by tree and brush canopies, were not included in the correlation of open grass range sites with PVI. Accordingly, the correlation of 5 grass sites and 4 bare soil sites with PVI was highly significant ($r^2=0.938^{**}$) indicating a potential for estimating the forage production of open range areas using LANDSAT MSS digital data with a standard error of estimate of $Sy \cdot x = \pm 496$ kg/ha.

Table 3. Various range sites in Willacy County, Texas, sampled in October 1975 and January 1976 for herbaceous biomass production (kg/ha).

Range site	Symbol	Forage production	
		October 1975	January 1976
----- kg/ha -----			
Deep Sand			
Improved Native Grass	GD	1884	--
Native Mesquite	M	604	426
Tight Sandy Loam			
Improved Aliciagrass	GA	3730	1632
Improved Native Grass	GT	4752	2100
Native Brush	B	404	284
Sandy Mound			
Native Oak Trees	O	--	280
Salty Flat			
Native Grass	GS	660	414
Coastal			
Native Grass	GC	2922	1664
Soils			
Sand Dunes	D	0	0
Idle Cropland	I	0	0
Tidal Flats	T	0	0
Lagunas			
Wet	L	0	0

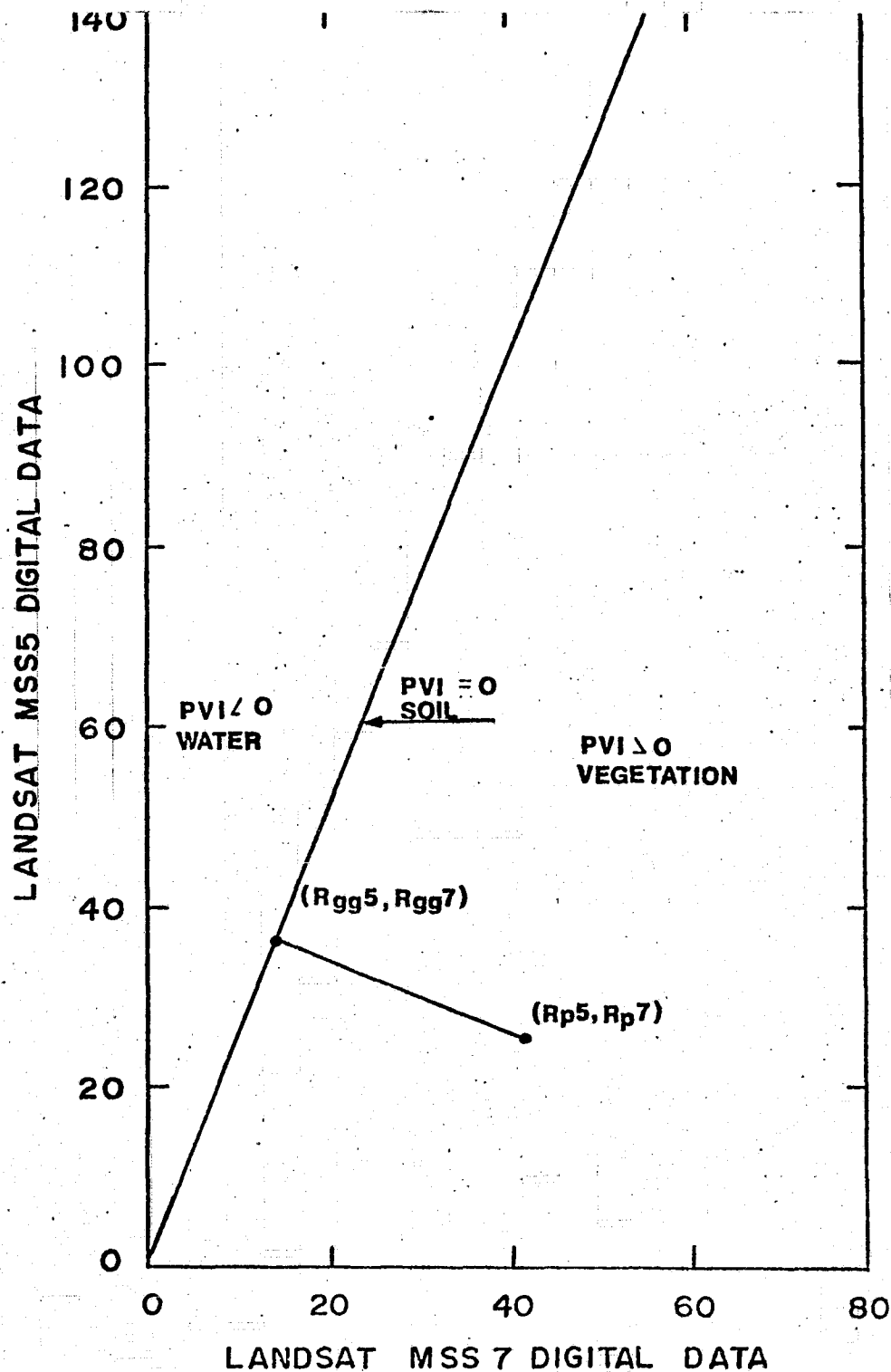


Figure 2. Soil background line determined using LANDSAT digital data, collected on April 2, May 6, June 3, July 10, and October 17, 1975, from bands 5 and 7. Data points falling to left of line yield negative values of PVI, points falling on the line yield zero values for PVI, and points to the right of line yield positive values of PVI. A candidate vegetation point (R_p) is defined in terms of bands 5 and 7 as (R_{p5}, R_{p7}) and its perpendicular intersection on the bare soil line is defined as (R_{gg5}, R_{gg7}).

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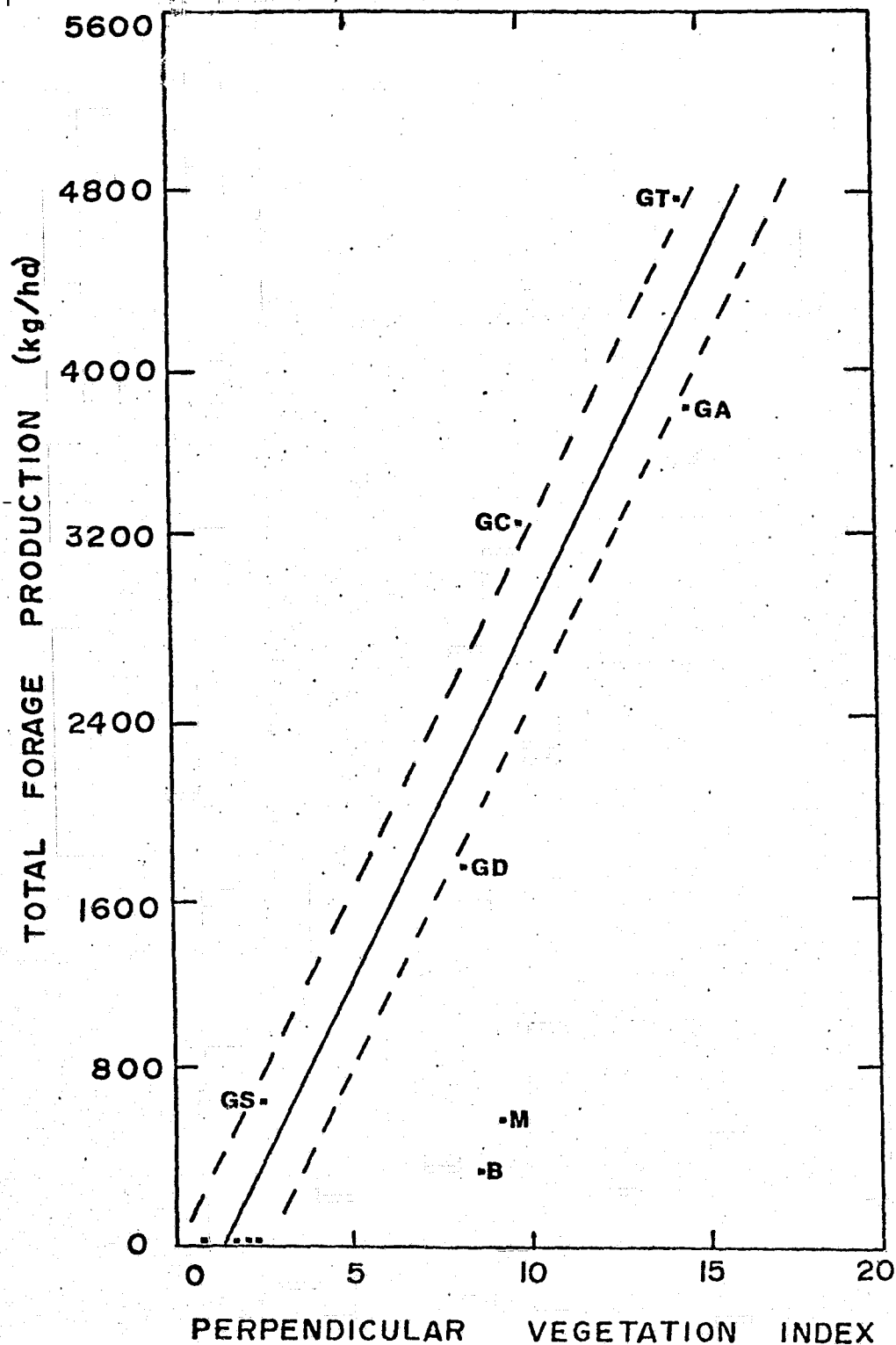


Figure 3. Regression analysis of total forage production (herbaceous biomass), collected on October 3, 1975, with the perpendicular vegetation index determined from LANDSAT MSS bands 5 and 7 for October 17, 1975, digital data. The regression included 5 improved native grass sites (GT, GA, GC, GD, and GS) and 4 soil sites (unidentified points close to graph origin); thus, $n = 9$ range sites. Native mesquite (M) and native brush (B) sites were not part of the regression analysis.

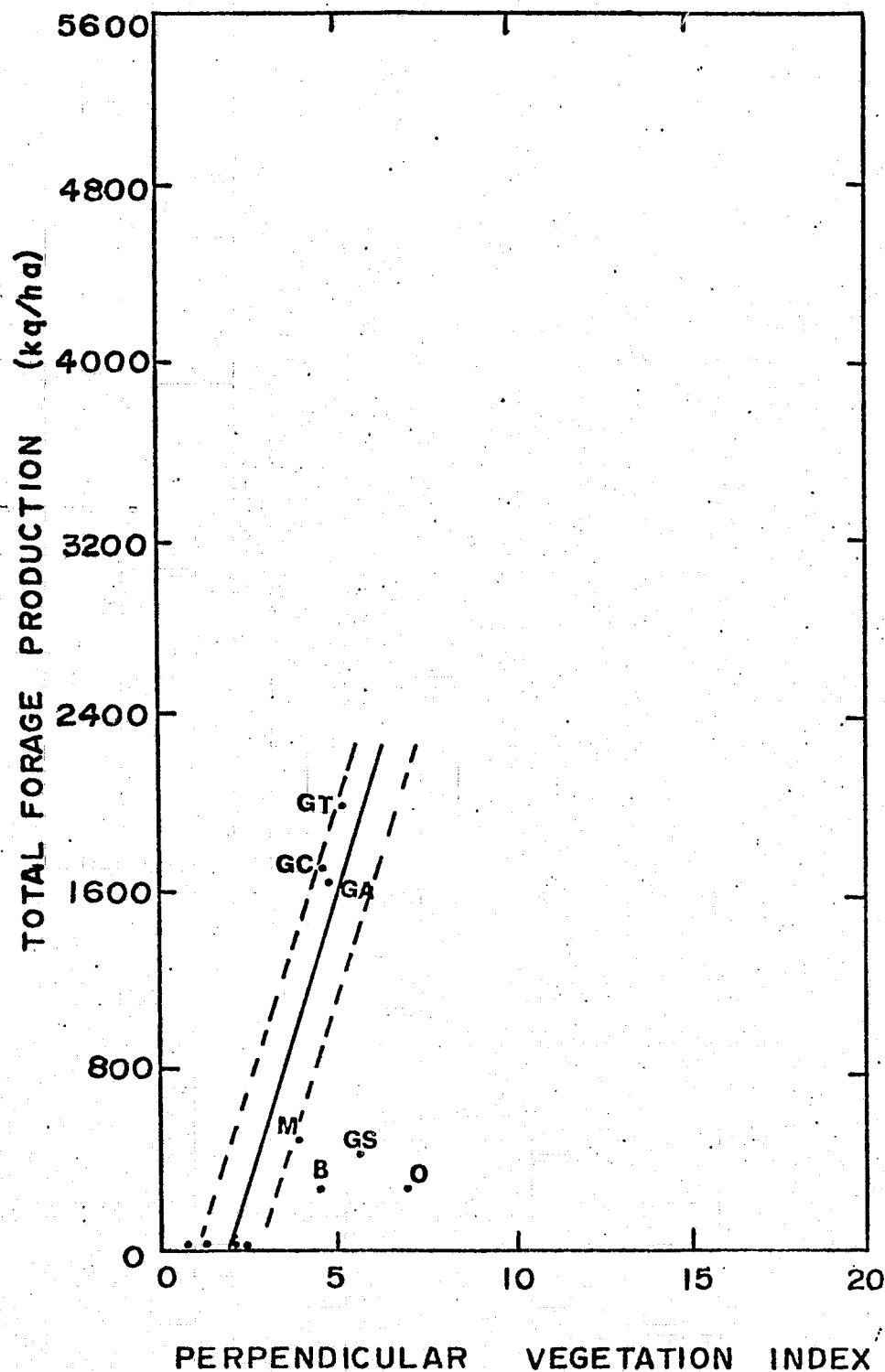


Figure 4. Regression analysis of total forage production (herbaceous biomass), collected on January 6, 1976, with the perpendicular vegetation index determined from LANDSAT MSS bands 5 and 7 for December 10, 1975, digital data. The regression included 3 improved native grass sites (GT, GC, and GA), a native mesquite (M) site, and 4 soil sites (unidentified points close to graph origin); thus, $n = 8$ range sites. Native brush (B), native oak trees (O), and salty flat-native grass (GS) were not part of the regression analysis.

For January, biomass data (dormant season) was not collected for the deep sand improved grass (GD) range site, leaving 4 open grass sites for correlation with the PVI. The mesquite tree site (M) appeared to fit the linear relation for grass site, indicating that the deciduous mesquites were in winter dormancy so that light penetrated to the grass understory; thus, this site was included in the open grass site correlation analysis for January. The reason for the deviation of the salty flat site (SF) from the linear relation of the other grass sites is not known. Again, native brush (B) and oak tree (O) sites were not included in the correlation with the open grass sites. This correlation of 3 grass sites, 1 mesquite tree site, and 4 bare soil sites was also highly significant ($r^2=0.834^{**}$) indicating further that the PVI estimates forage production of open range areas.

The October and January dates have almost the same intercept and slope values. Hence, the data were combined. The combined data yielded a highly significant correlation ($r^2=0.908$) showing that one linear expression ($\text{Prod.} = -363 + 327 \text{ PVI}$) can estimate forage production for both dates with a standard error of estimate $\text{Sy.x} = \pm 468 \text{ kg/ha}$.

These results indicate that forage production differences can be observed using LANDSAT digital data and a forage production map produced for a given range site. This information may be useful for balancing livestock numbers with available forage, determining range readiness, and evaluating cattle distribution over large pastures.

C. Significant Results:

Wavelengths to use for various applications have been determined as follows:

<u>Application</u>	<u>Wavelength(s), μm</u>	<u>Reasons or Effect</u>
Lead (Pb) toxicity	0.5 to 0.75	Decreased chlorophyll content
	1.35 to 2.5	Decreased water content
Soil erosion by wind	0.75 to 1.3	Soil and straw distinguished
Peperomia i.d.	2.2	Stored water eliminated
		2.2 μm peak
Ultraviolet damage to plants	0.26 to 0.36	First leaf layer absorbs $\approx 95\%$ of I_0
Ozone damage	1.35 to 2.5	Leaf hydration difference
Wheat vigor	0.55, 0.90, 1.10	Positive correlation with green biomass
Wheat discrimination from soil	0.65, 0.73	Plants obscure soil;
	1.65, 2.2	Water in plants absorbs strongly, dry soil reflects strongly
Distinguishing succulent vs. woody species	1.35, 1.60	Water content difference
	2.20	
Detection of weed, silverleaf sunflower	0.45 to 0.75	Dense white pubescence

Reflectance measurements with a field spectroradiometer on 9 dates (between December 9 and April 8) during the growing season of two wheat varieties, Milam and Penjamo, showed that the reflectance curves had the characteristic shape of vegetated surfaces by 4 weeks after emergence. Green light (0.55 μ m) reflectance was maximal and between water absorption bands (1.65 and 2.2 μ m) reflectance was minimal when green vegetation development was greatest.

Computer classification was accomplished for our 81,000-hectare coastal rangeland area for October 13 and December 10, 1975, overpass dates. A hard freeze occurred between these two dates and many of the deciduous woody species (mesquites, etc.) defoliated so that more light penetrated to the herbaceous understory in December than in October. Thus much of the "mixed brush rangeland"--20-80% ground cover of woody species--was classified as "grassland" in December overpass.

The perpendicular distance of a vegetation MSS measurement from the soil background line (perpendicular vegetation index, PVI) was proposed and tested as an index of plant vegetation development. Since the vegetation line is perpendicular to the soil background line, its intersection on the soil background line can be calculated and be interpreted in terms of soil water content, crusting, and tillage.

The LANDSAT data space surrounding the soil background line for MSS5 and MSS7 was divided into 10 decision regions corresponding to water; cloud shadow; low, medium, and high reflecting soil; cloud tops; low, medium, and dense plant cover; and, a region into which no LANDSAT data are expected to fall, called threshold. It was demonstrated that, using a table lookup procedure and printer symbols for each decision region, LANDSAT study areas or scenes could be gray mapped to meaningfully display vegetation density and soil condition categories without prior knowledge of local crop and soil conditions.

D. Publications:

Arkin, G. F., H. Huddleston, Ray Jensen, and C. L. Wiegand. 1976.

The future role of a crop model in large area crop yield estimating. Agronomy Abstracts. p. 8.

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Everitt, J. H., and J. A. Cuellar. 1976. Use and management of the rangelands of Hidalgo County, Texas. Rangeland's Journal 3(5):155.

Hart, W. G., H. W. Gausman, and R. R. Rodriguez. 1976. Citrus blackfly (Hemiptera: Aleyrodidae), feeding injury and its influence on the spectral properties of citrus foliage. J. Rio Grande Valley Hort. Soc. 30:36-44.

Gausman, H. W., R. R. Rodriguez, and C. L. Wiegand. 1976. Spectrophotometric reflectance differences between dead leaves and bare soils. J. Rio Grande Valley Hort. Soc. 30:103-108.

Richardson, A. J., R. Riojas, and C. L. Wiegand. 1976. Computer-aided inventory of sugarcane in Hidalgo County, Texas, using LANDSAT-I data. J. Rio Grande Valley Hort. Soc. 30:95-102.

Wiegand, C. L., A. H. Gerbermann, A. J. Richardson, and P. R. Nixon. 1976. Experience relating LANDSAT data to grain sorghum plant development and yield, with implications for large area yield. Agronomy Abstracts. p. 13.

E. Recommendations:

None.